An Introduction to Astronomical Filters Part 5

Do Light-Pollution Filters Work?

By Jim Thompson

In my preceding four articles, I have attempted to introduce astronomical filters, from simple colour filters for planetary work, through deep-sky filters, and most recently specialty filters. But, based on price alone, I imagine that the amateur astronomer is most interested in choosing the right light-pollution (LP) filter. A hundred dollars (or more) is a lot to invest in a piece of glass that may not actually do anything. I have performed my own tests on LP filters, both with an eyepiece and an astro-video camera, but my hands-on tests have been limited to only a couple of different filter types and brands. The sheer numbers of filters on the market make it pretty much impossible to compare them all side-by-side using observations alone. So, what do we do now?

Luckily for us, there is a solution, one involving lots and lots of number crunching – and I love number crunching. One of the results of my research into filters has been the creation of a database of filter spectral responses. Some response curves are from technical papers, many are from websites, some are from filter packaging that astronomy supply store owners have been nice enough to scan for me, and some I have even measured myself. All totaled, I have spectral response curves for over 100 interference type filters, plus another 50 or so colour filters. In theory, I should be able to multiply the spectral response of each filter times the emission spectrum of a typical deep-sky object (DSO), pass it through the spectral response of my detector (human eye or CCD), and add it up to figure out how much brighter the DSO is compared to the background. Sounds easy right? Did I mention I love number crunching?

The first thing I did was format my filter data so that it was amenable to doing calculations on it. I parsed the data from all 14 deep-sky filter categories, plus the colour filter data, so that it was continuous from 200 nm to 1200 nm in 5-nm steps. I chose this large wavelength range in order to handle the wide spectral response of a typical CCD. In cases where I was missing data in the UV or IR bands, I filled it in with a best guess: zeros in the UV and an average of known filter responses in the IR. The result was a big spreadsheet table (**Table 1**), ready to multiply against something.

Next I selected my detectors: the dark-

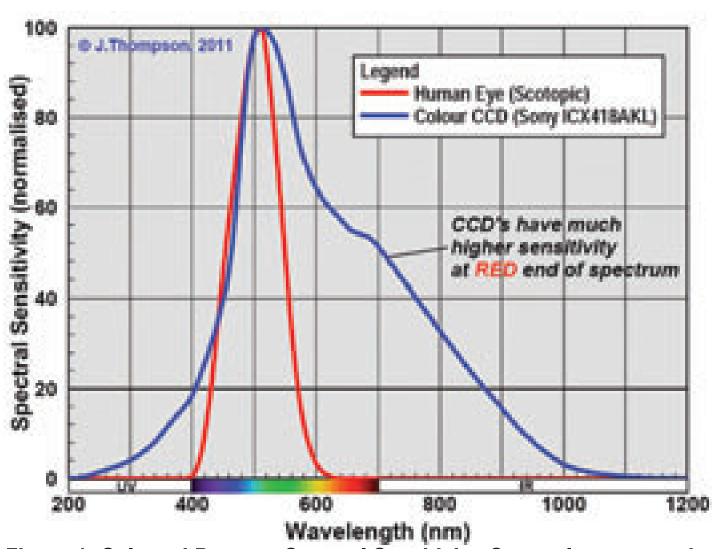

Figure 1. Selected Detector Spectral Sensitivity: Spectral responses for the two sensors used in my analysis.

Table 1	
Category	**Prerequisite**
1. H-alpha Group A:	H-alpha pass band is >10 nm wide.
2. H-alpha Group B:	H-alpha pass band is <10 nm wide.
3. H-beta Group A:	Pass H-beta wavelength with >90% transmission.
4. H-beta Group B:	Pass H-beta wavelength with <90% transmission.
5. O-III Group A:	Allow both doubly ionized Oxygen wavelengths to pass.
6. O-III Group B:	Allow only one doubly ionized Oxygen wavelength to pass.
7. Narrow Band:	H-beta + O-III pass band is <35 nm wide.
8. Medium Band:	H-beta + O-III pass band is >35 but <50 nm wide.
9. Wide Band:	H-beta + O-III pass band is >50 but <70 nm wide.
10. Extra-Wide	Band H-beta + O-III pass band is >70 nm wide.
11. Multi Band:	More than two major pass bands in the visible range.
12. IR Cut:	Blocks wavelengths above 700 nm.
13. Special A:	Filters especially designed for planets or other special object viewing.
14. Special B:	Special filters for contrast enhancement based on Neodymium-infused glass.

Table 1. Deep-Sky Filter Categories: These 14 categories are of my own invention, chosen to help organize the large number of available filters.

adapted (scotopic) human eye and the Sony ICX418AKL colour CCD. This particular CCD was selected because it is the sensor that is in my astro-video camera, a Mallincam Xtreme. The CCD has a significantly higher sensitivity in the red and near-infrared parts of the spectrum compared to the eye, so I was very eager to see how the two compared to each other. Once I began my rough calculations, I quickly determined that I also had to choose a telescope configuration. I chose a configuration relevant to my own observing: an 8-inch f/10 Schmidt-Cassegrain with eyepiece/camera effective focal length of 8 mm. This gives about 250x power and a field of view (FOV) of approximately 12 arcminutes.

The last piece of the puzzle was the target DSO. I anticipated differences in filter performance depending on whether the DSO was a bright O III-rich nebula, a dim H-alpha nebula, or a galaxy. As a result I chose a typical representative from each group as shown in **Figure 2:** M27, the Dumbbell Nebula (a bright nebula); NGC7000, the North American Nebula (a dim nebula); and M51, the Whirlpool Galaxy. Finding spectral response data for these objects was relatively easy. Luckily there is a lot of research ongoing in this area, so data was reasonably plentiful on the Internet.

Whoops, I almost forgot the most important, but yet uninvited guest at our party, the reason we're all here: light pollution. Figuring out how to account for light pollution was very tricky. It took me a long time, but I eventually decided to base it on the notion of "limiting visual magnitude." Under natural dark skies, the dimmest star you can see with the unaided eye is around magnitude +7. Any glow seen in the sky under these conditions is due to natural phenomenon like ionized oxygen or sodium in the upper atmosphere. Where I live, in the middle of Ottawa, I average about magnitude +3.5 skies. The sky glow is due to not only the natural contributors, but also the unwanted contribution of man-made outdoor lighting. On evenings when the Moon is full, or nearly so, my limiting magnitude is more like +2. In these conditions, the sky glow is a sum of natural sky, man-made LP, and the Moon. See **Figure 3**.

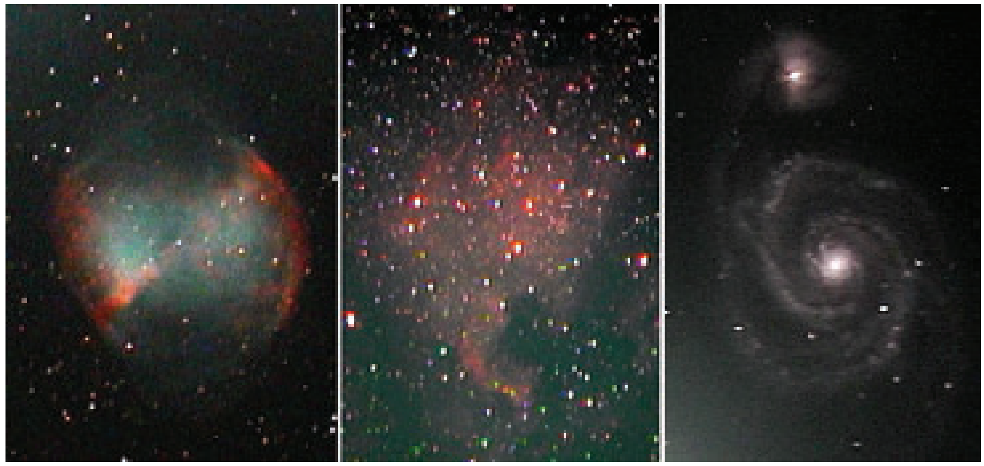

Figure 2. Selected DSO Targets: Anticipating differences in filter performance, three basic types of DSO have been selected.

The key to the whole puzzle now is Vega. The star visual magnitude system is referenced from Vega, which years ago was assigned magnitude 0.0 (it is actually not quite zero today, but is close enough for my needs). After much digging into websites, books, research papers, etc., I was able to come up

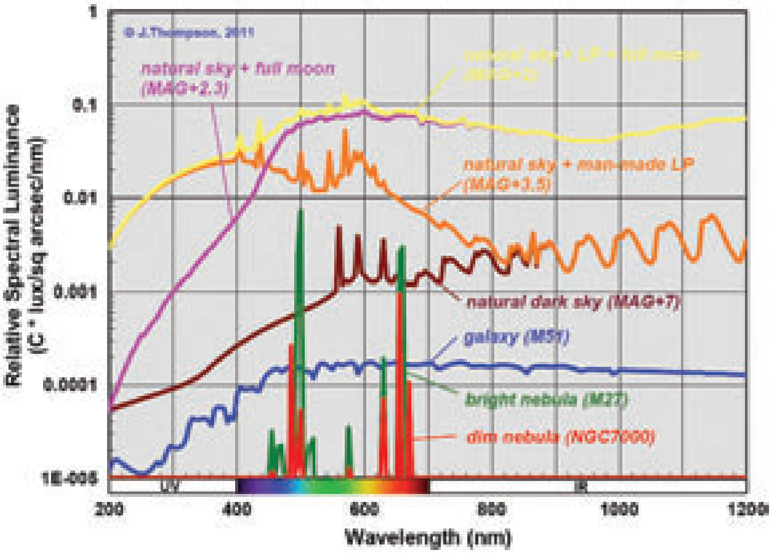

Figure 3. Light Pollution Contributors: By combining these three different sources of light pollution, representative observing conditions can be simulated.

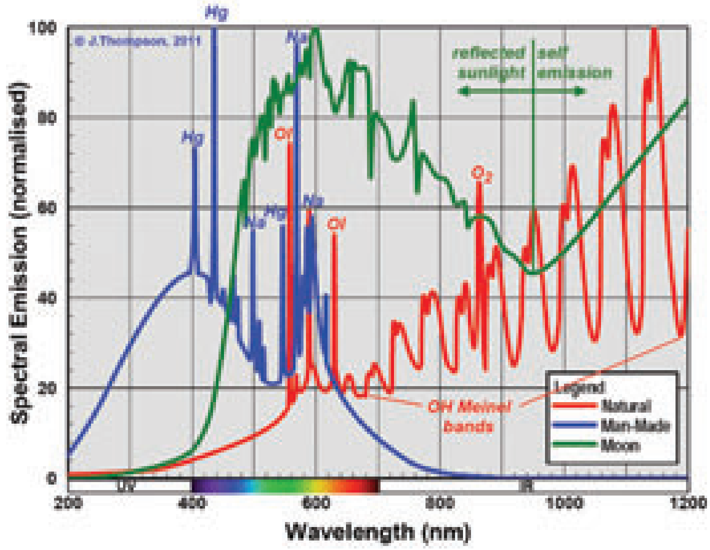

Figure 4. Absolute LP and DSO Emissions: These spectral emissions are to scale, allowing for them to be added together and compared with and without filters.

with "typical" examples of emission spectra for my three sources of LP, plus Vega. I filtered these emission spectra through the spectral response of the human eye, integrated over the visual band (400 to 700 nm), to come up with a total perceived brightness per unit area. I then determined what constant I would have to multiply each emission spectra by to get the correct brightness relative to Vega based on each type of LP's limiting magnitude. I similarly determined the constant to multiply each of my DSO emission curves by in order to get the correct visual magnitude for them. The end result was a set of spectral emission curves for each of my LP sources and DSOs that was scaled into the same absolute units. It was a lot of effort to get to this point, but I could now see the light at the end of the tunnel – my plan might just work! With my filter, detector, target and LP spectral data now all in order, it was time to start number crunching. I first concentrated on the human eye as the detector. To be able to easily compare the performance of all the filters to each other, I calculated the signal-to-noise ratio (SNR) for each filter-DSO-LP combination. The SNR is defined as: SNR = (luminance DSO + luminance Sky)/(luminance Sky). **Figure 4** shows Absolute LP and DSO Emissions.

The larger the value of SNR, the easier the DSO will be to see against the background sky. I have set the lower limit for detection at SNR=1.02, which is a rule of thumb that I remember from an old episode of the PBS science show Connections. Therefore if the calculated SNR is less than 1.02, the DSO will in theory not be visible with the human eye through my selected telescope-filter setup in the particular LP conditions simulated. To get a general feel for how my results were going to turn out, I first considered just one representative filter from

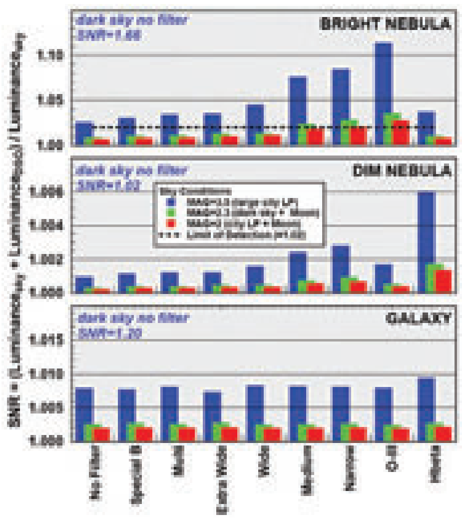

Figure 5. Filter Visual Performance by Category: A representative filter from each category has been plotted above for a range of LP levels and DSOs.

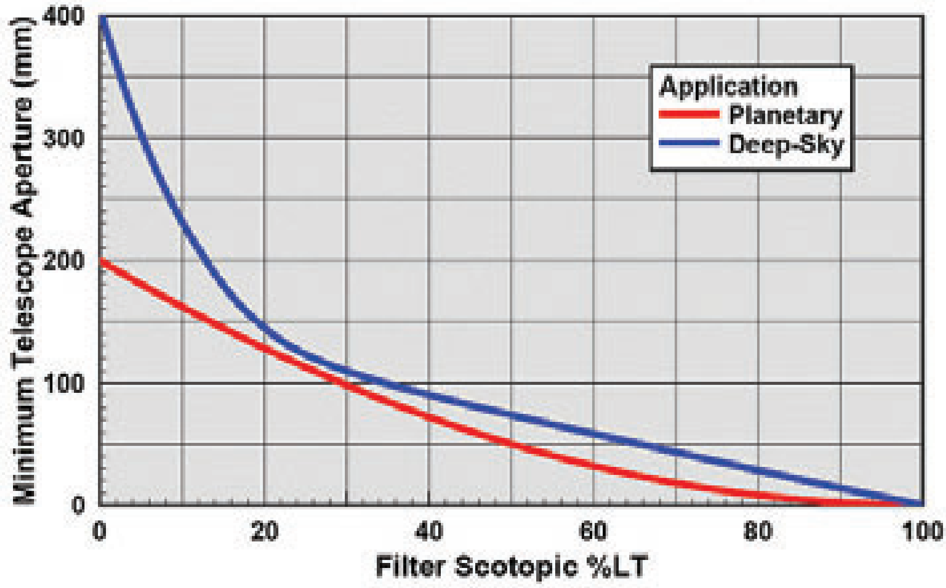

Figure 6. Recommended Minimum Percentage LT Versus Aperture: All filters reduce the amount of light getting to the eye. It is important to pick a filter that is not too dark for your aperture.

each filter category which are included here.

Multi Band: IDAS LPS-P2
Extra Wide Band: DGM GCE
Wide Band: Lumicon Deep Sky
Medium Band: Astronomik UHC
Narrow Band: Meade Narrow Band
O-III: Astronomik O-III
H-beta: Astronomik H-beta
Special: Canadian Telescope Moon & Sky Glow

I did not look at H-alpha or IR-Cut filters for the eye as detector, but did later for the CCD case. I plotted the predicted SNR values for a magnitude +3.5 (LP), +2.3 (Moon), and +2 (LP + Moon) sky, with and without filters. The results were very consistent with what I have experienced in practice (see **Figure 5**).

Based on my predictions, the bright nebula is just barely visible with light pollution and no filter when there is no Moon, but is not visible at all when the Moon is up. Adding a LP filter greatly increases the SNR, making the object much more visible even on moonlit nights. As the narrowness of the LP filter increases, so does the SNR, with the O-III filter resulting in the highest-contrast view. For the dim nebula, my predictions say that I can not see this object when under light-polluted skies, even with filters, and can just barely see it when under dark skies. This is consistent with my observing experience. If I were to use a faster f/ratio or larger aperture, then the H-beta filter looks like it would give the best-contrast view. Finally for the galaxy, under dark skies the object is predicted to be easily visible (true), but when under light-polluted skies it is not possible to see it, with or without a filter using my telescope setup.

The consistency of my predictions with my actual observations was very comforting as it confirmed that my methodology is sound. It was now time to run all the deep-sky filters through the same calculation. Not surprisingly, the performance of all the deep-sky filters seems to follow a well-defined distribution when plotted against their luminous transmissivity (%LT). Some outliers were observed, but most filters fit along the trends shown in **Figure 7**. This is interesting, since choosing the best filter for your telescope setup becomes as simple as finding the lowest percentage LT your telescope can support based on your aperture and picking one of the filters that sits at that location on the SNR curve. These curves also determine the best you can hope to achieve with a filter depending on the DSO and seeing conditions. The curves can also be used to separate good filters from bad ones; good ones should be on or above the curve, bad ones are below the curve. A comprehensive table listing every and each filter's SNR and percentage LT values is simply too large to include in this article. So, please contact me directly if you want to see these results.

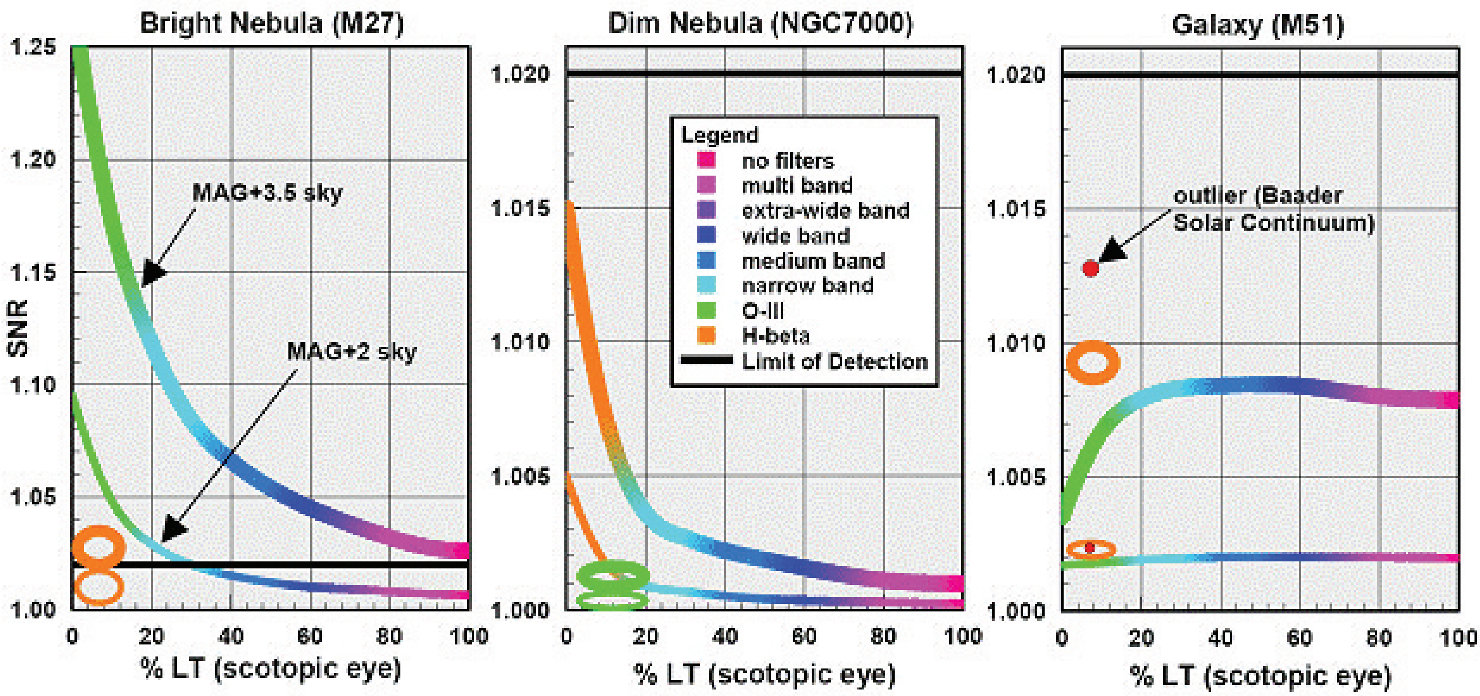

Figure 7. All Deep-Sky Filters Compared: These plots are a simplified view of predicted performance for all interference-type filters for which I have data.

I ran all of the colour filters through the same analysis and found that they really are not that great as LP filters. On bright nebulae, a small improvement in SNR was achieved by using a green or yellow filter, but the resulting SNR is about half that of a proper LP filter of the same percentage LT. On dim nebulae, colour filters did nothing except make the view dimmer. On galaxies, green and yellow filters gave a slightly better SNR than LP filters of the same percentage LT, but similar to LP filters, the improvement in SNR over no filter was very small – not enough to raise the SNR above the level of detection for my assumed telescope configuration.

You may wonder why I even bothered to consider colour filters for suppressing light pollution. The reason is that colour filters are absorption-type filters, which are not sensitive to the angle of the light through the filter. In applications where a very wide FOV is desired, interference-type filters do not perform well. If a colour filter can be found that gives a comparable improvement in SNR to an interference filter, the colour filter would be the preferred choice when using a wide-FOV instrument such as a pair of binoculars or wide-angle DSLR lens.

Based on the results of my analysis, LP filters do actually work. Nothing can beat dark skies, but as long as one chooses the right filter for their telescope setup, significant improvements in your view can be achieved on nebulae under light-polluted skies. Based on my analysis, there is no significant improvement possible using a filter when viewing galaxies. This finding may, however, change if your detector is a CCD, which I will discuss in my next installment in this article series.

Finally, it is important to note that the results I have presented here are specific to the telescope configuration, DSOs, and LP levels that I have modeled. If I had chosen a telescope with a faster f/ratio or larger aperture, the predicted SNR curves would be shifted upwards (i.e., more observable). Similarly, if the light pollution is milder or the DSOs had higher surface brightness, the SNR curves would also move up.

For questions, contact me at: karmalimbo@yahoo.ca, or visit my website at www.karmalimbo.com/aro. ATT